

amt-2014-339: The Radio Occultation Processing Package ROPP

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Response to Interactive comment by Anonymous Referee #2

We thank the referee for his or her careful reading of the paper, and for making some useful and informative criticisms.

General comments:

- In my opinion section 1 (Introduction) should also notice other RO processing systems where ROPP is one of them.

We respectfully disagree. The subject of this paper is ROPP, not RO data processing systems in general, and to discuss others in the Introduction would invite comparison later. Such a comparison would be a worthwhile exercise, but it is not the aim of this paper, which is simply to showcase the capabilities of ROPP. We feel that the statement (Page 158/Lines 18-19) "This paper describes one such package, ROPP." clearly implies that other RO processing systems exist.

- In addition when mentioning NWP and climate monitoring in section 1 some more references should be added:
 - For NWP mention e.g, some centers which are using RO data in their assimilation procedures (e.g., Cucurull and Derber (2008), Healy and Thépaut (2006), Aparicio and Deblonde (2008)).
 - For climate monitoring cite e.g., Steiner et al. (2011) and/or the RO-trends papers of Steiner et al. (2013) and Ho et al. (2012).

Thank you. We will extend P158/L14 to say: "..., and have led to the extensive use of RO data for atmospheric research (e.g. Schmidt et al, 2010, Zhang et al, 2010), for assimilation in Numerical Weather Prediction (NWP) models (e.g. Cucurull and Derber, 2008, Healy and Thépaut, 2006, Aparicio and Deblonde, 2008) and for climate monitoring (e.g. Steiner et al., 2011, Ho et al., 2012).

- Regarding the structure of the paper I suggest combining sections 3 to 8 into one section called something like "... detailed view on ROPP ...".

Good idea – thank you. We will Introduce a Section 3 called "Detailed view of ROPP", which says "There follow more detailed descriptions of the ROPP modules.", followed by 3.1, "Utility module" through to 3.6, "Testing module".

- I suggest integrating section 11 in the Introduction.

Agreed; we will place the text of Sec 11 in a new paragraph after P159/L11.

- In my opinion section 9 is somehow overrepresented. I suggest either integrating it into the overview section (section 2) or into section 3.

Agreed. We will delete Sec 9 and Table 8, and replace them with a new Sec 3.7, "Third party software", which will say:

“Full implementation of ROPP requires the installation of some standard freely available third party software packages, principal among which is the netCDF library for general data input and output. Some tools need a BUFR library for reading or writing NWP data in that format. Another uses routines in a GRIB library to extract background profiles from a gridded dataset. The ROPP documentation clearly indicates which packages are needed by which modules and tools. Naturally, any licence restrictions associated with these packages must be adhered to by ROPP users.”

Minor comments:

- Please explain all acronyms at their first occurrence.

Very well. We will add footnotes defining EUMETSAT (P158/L20), GRAS (P159/L3), Metop (P159/L3), COSMIC (P159/L5), CHAMP (P159/L5), GRACE (P159/L5), C/NOFS (P159/L5), SAC-C (P159/L5), TerraSAR-X (P159/L5), TanDEM-X (P159/L5), PAZ (P159/L5), ISO (P169/L18), ANSI (P169/L18), IDL (P169/L21). We will also remove the consequently redundant definition of EUMETSAT on (P170/L12).

- Cite tools which are used by ROPP at their first occurrence, i.e., in the overview section: e.g.: the 2D-Operator (Healy2007), or the different tropopause height definitions (e.g. WMO 1957) and methods and not later in the text.

Very well. We will rewrite P161/L7-20 as follows.

“The preprocessing module contains tools to undertake the staged preprocessing from excess phase (i.e., the phase accumulated by the carrier wave during transit of the atmosphere and ionosphere above that which would be accumulated along a straight line path in vacuo between the transmitter and receiver) to bending angle, through to refractivity and dry temperature (Gorbunov et al, 2011). It also contains tools to diagnose tropopause heights from profiles of bending angle, refractivity, dry temperature or background model temperature (Lewis, 2009; WMO 1957).

The forward modelling module contains forward operators (including tangent linear, adjoint and gradient calculation code) for pressure-based, height-based and hybrid NWP model vertical grids, to generate refractivities and bending angles from model state variables (Healy and Thépaut, 2006). It also includes a 2-D bending angle calculation tool (Healy, 2007).

The 1D-Var module contains cost function minimisers that allow the retrieval of pressure/height, temperature and humidity profiles from refractivity or bending angle profiles, given colocated NWP model background profiles (Healy and Eyre, 2000, Rennie, 2010).

- p. 162 line 14: I would not state that the ROPP netcdf format is the “general format for radio occultation data” – I strongly recommend removing the “general”.

We mean it is general to ROPP, not to RO. However, we will remove the “, general”.

- Thépaut with accent aigu on the é (e.g., page 165 line 21).

Thank you; we will correct this (and in the references).

- p. 163 line 13, 14: Please rewrite these two sentences.

OK. We will write:

"In more detail, the tools in the `ropp_pp` module perform the following tasks. `ropp_pp_occ_tool` processes excess phase and amplitude data into refractivity, bending angle and dry temperature profiles, in the following steps."

- p. 165 line 12, 13: Please rewrite these two sentences.

OK. We will write:

"In more detail, the tools in the `ropp_fm` module perform the following tasks. `ropp_fm_bg2ro_1d` forward models 1D background fields into profiles of refractivity and bending angle, in the following steps."

Although not requested, we will similarly amend P166/L2 to read:

"In more detail, the tools in the `ropp_1dvar` module perform the following tasks."

- p. 163 line 21: Please specify more precisely how the combination of GO and WO bending angle is done.

OK, but there's not much to say. The WO and GO bending angles aren't 'blended' across the 25 km boundary, for instance. We will say: "Compute bending angles by geometric optics or wave optics (CT2) (Gorbunov and Lauritsen, 2004). By default, ROPP uses CT2 below 25 km and geometric optics above. The concatenated bending angles are then interpolated onto a common (i.e., the same for L1 and L2) uniformly spaced grid of impact parameters, whose default spacing is 100 m."

- p. 166 line 16, 17: It would be nice to see the difference between the two forward modeled bending angles in a plot.

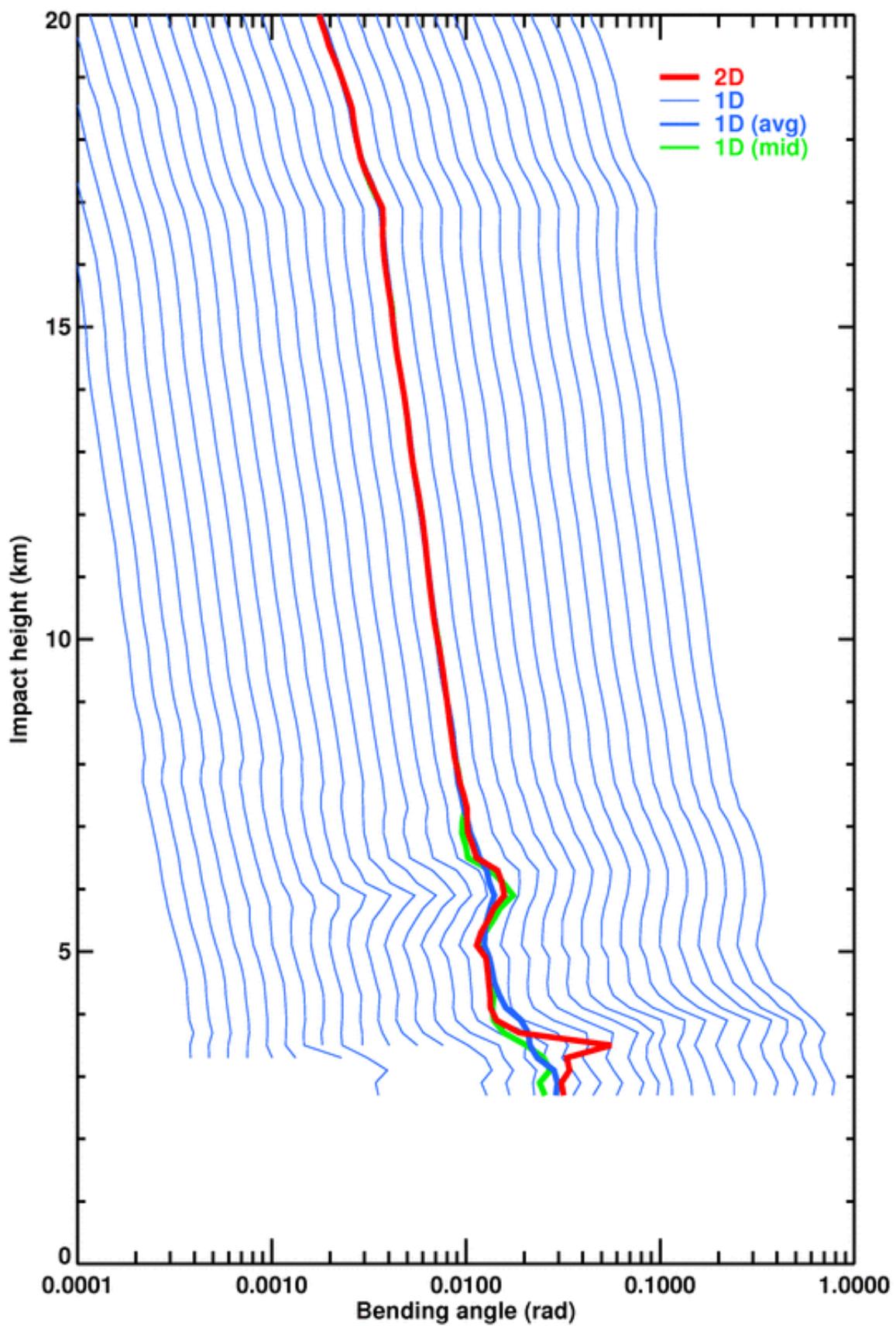
We thank the reviewer for raising this point, which has uncovered an error in the text – and the ambiguous ROPP documentation from which it is derived, and which will be corrected at the next release. In fact, the 2D operator only calculates the 1D bending angles at the *centre* of the section, not at each profile in that section. We will therefore amend the text to say:

"Compute the 1-D bending angle profile at the centre of the 2D occultation slice, using the Abel transform method of `ropp_fm_bg2ro_1d`, for comparison."

As for the substantive point: we agree it would be nice to see both bending angles, but we have chosen not to show any results from the 2D bending angle operator, because we feel it is too specialised an area for this paper, the aim of which is simply to give an overall summary of the capabilities of ROPP.

But since the reviewer has expressed an interest, here is a plot of the 2D-calculated bending angle, the individual 1D bending angles at each horizontal location (offset for clarity, and generated 'by hand' for this exercise), the average of those 1D bending angles and the 1D bending angle in the middle of the section, as output by ROPP. (This is the test data distributed with the ROPP package, not the profile studied in the paper.) There are clearly rather large differences between the 2D, 1D(avg) and 1D(mid) bending angles in the lower atmosphere, as would be hoped and expected. In particular, the 2D bending angle has captured something of the kink at about 4 km which is seen in about half of the 1D profiles, but not in the centre one and not in the average. The kink at about 6 km is, however, captured by the 2D bending angle and the middle one of the 1D profiles. Questions of detail, representativity, consistency, sensitivity to horizontal gradients etc all now present themselves, and responding to these would, we feel, detract from the thrust of the paper.

1D and 2D bending angle comparisons



- p. 163, line 24, 25: Introduce LC.

We will say “- Perform “linear combination” (LC) ionospheric correction ...”.

- p. 172: last word on line 3: typo: log → lot

No, it is a log of the changes, i.e. a record of them.

- p. 189 Figure 5: The top panels do not have upper axis descriptions for specifying the $(o - b)/o$ part of the plot.

Thank you for bringing this to our attention. Fig 5 was incorrectly cropped. The top axes on the top two panels should be titled “Bending angle difference (%)” and “Refractivity difference (%)\”, with scales going from -10 to 10. Fig 5 should also show the occultation ID (OC_20121001010210_C001_G008_UCAR) above it.

In fact, Figs 2, 3, 4 and 5 have all been over-cropped like this. We will correct all of them before publication.

- p. 189 Figure 5: Top right panel: add the closing bracket of the unit.

This is another consequence of the over-cropping (in the horizontal this time), which will again be put right before publication.